Rejection of Backgrounds with the DMTPC Dark Matter Search Using Charge Signals

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Outline

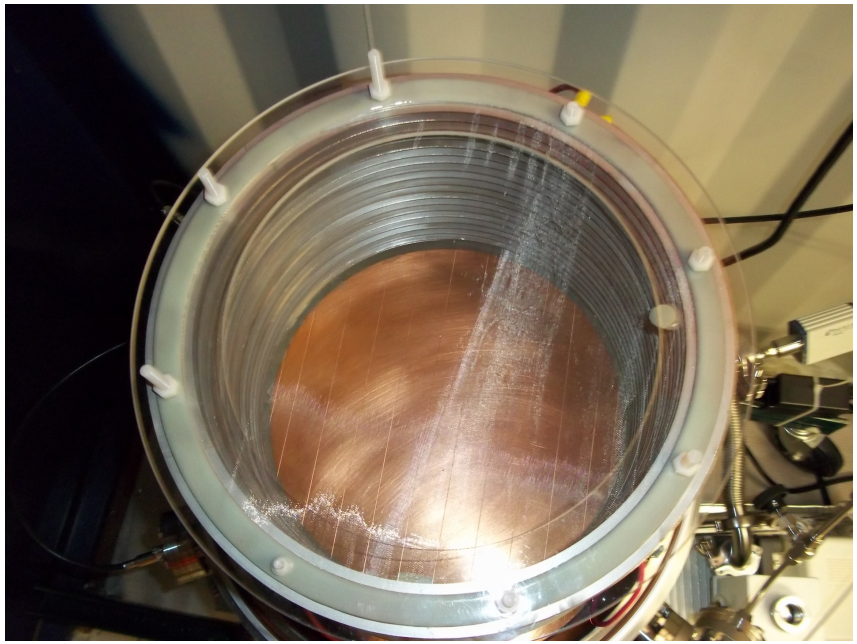
- The DMTPC Experiment
- Readout Channels and Analysis
- Discrimination of Electron Recoils
- Future Outlook and Conclusions

The DMTPC Experiment

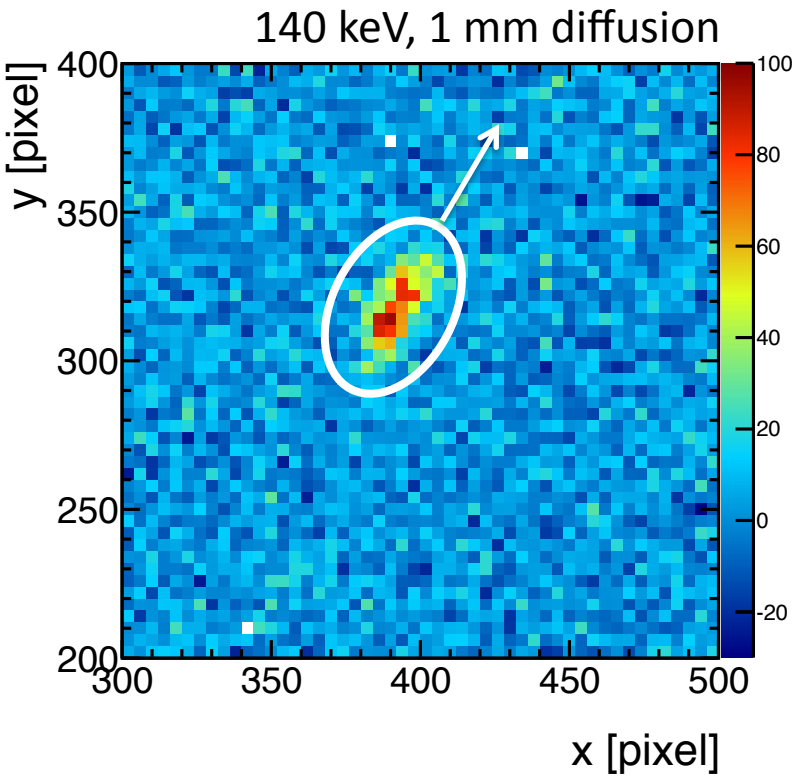
Dark Matter Time Projection Chamber
Institutions:

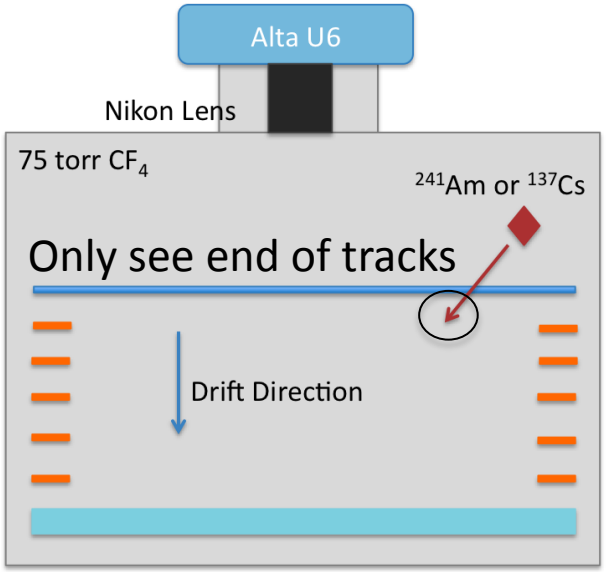
- Boston University
- Brandeis University
- Bryn Mawr College
- Massachusetts Institute of Technology
- Royal Holloway, University of London

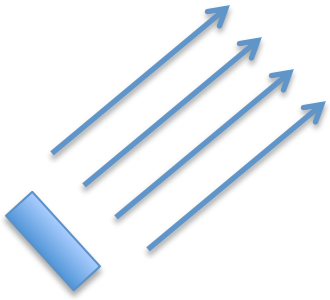
Detector Design Parameters



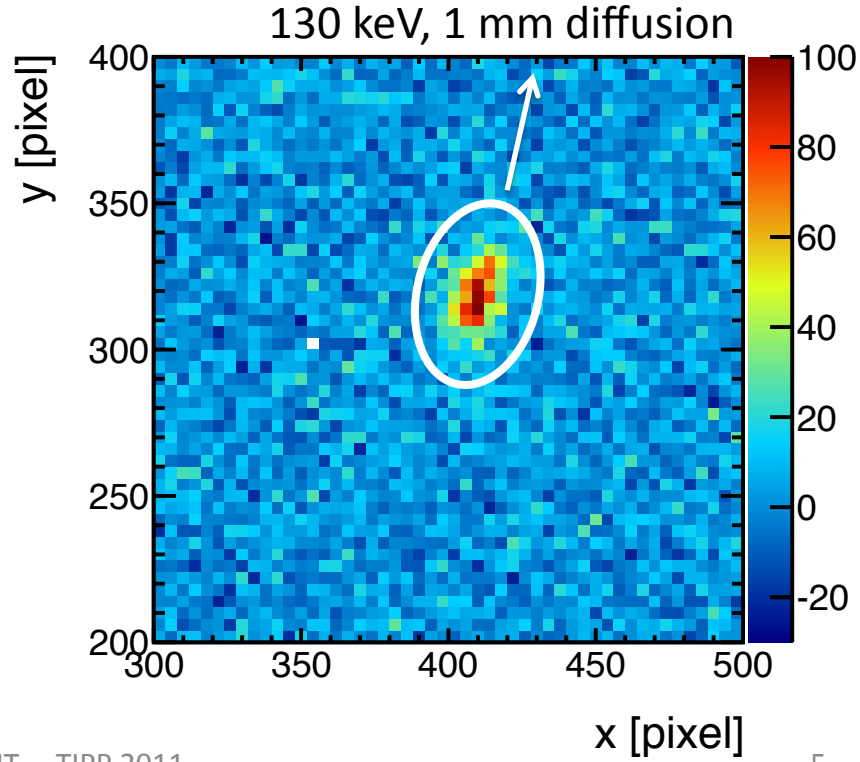
Gas	50-100 torr CF_4
Drift Field	250 V / cm
Ampl. Field	10-15 kV/cm
CCD	1 Mpix, 24 micron pixel, read out as 4x4 pixel bins Detect 1 γ / 10^4 e-
Gas Gain	~5 x 10^4
F Recoil Range	1 – 2 mm
F Recoil Energies	50 keV – 200 keV
Imaged Region	~250 cm^2/CCD
Diffusion	1 mm*sqrt(z/25cm)



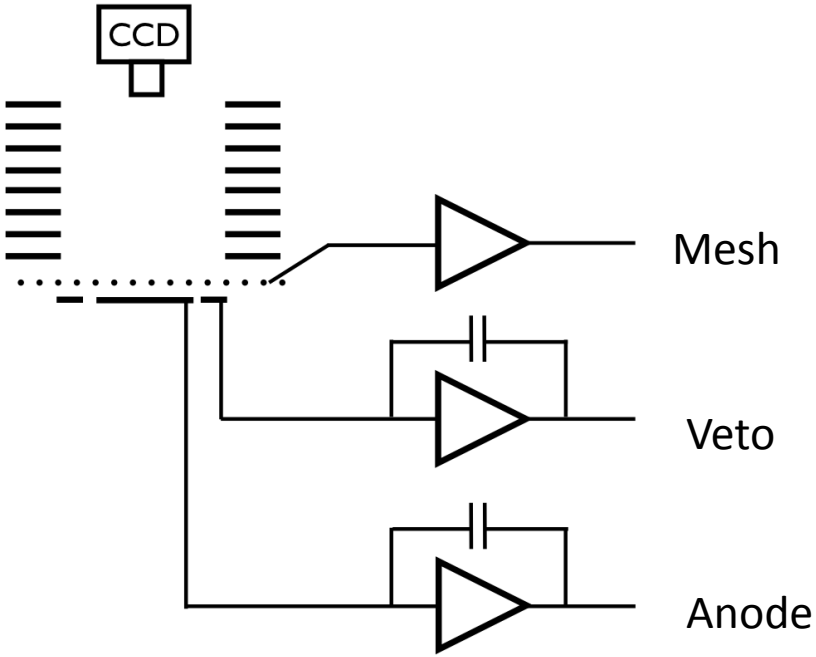




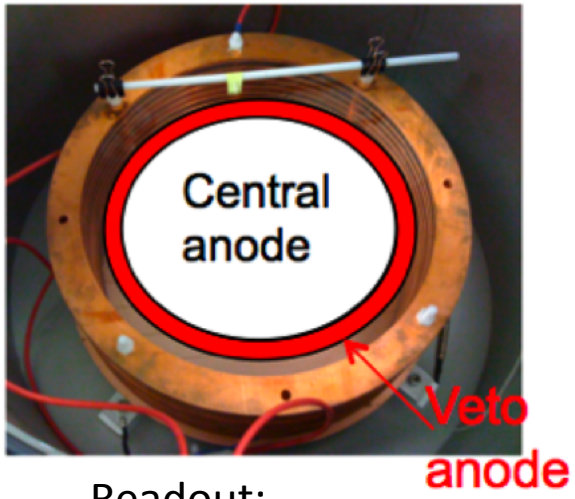
^{241}Am Alphas



Charge Readout Channels



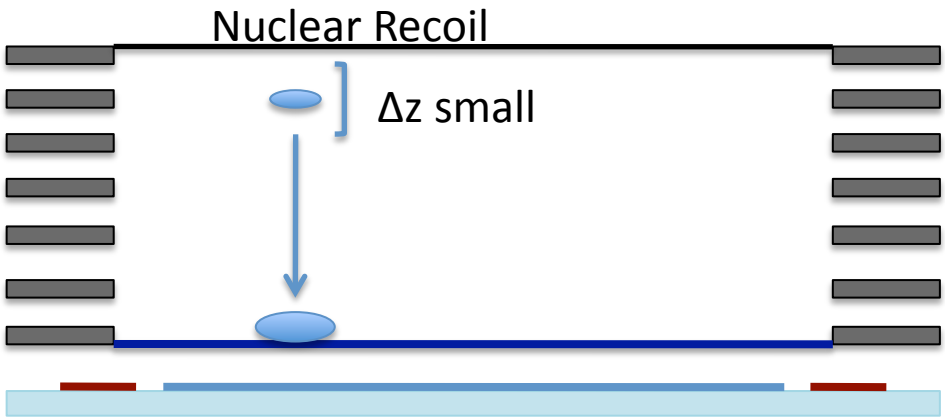
R&D Detector



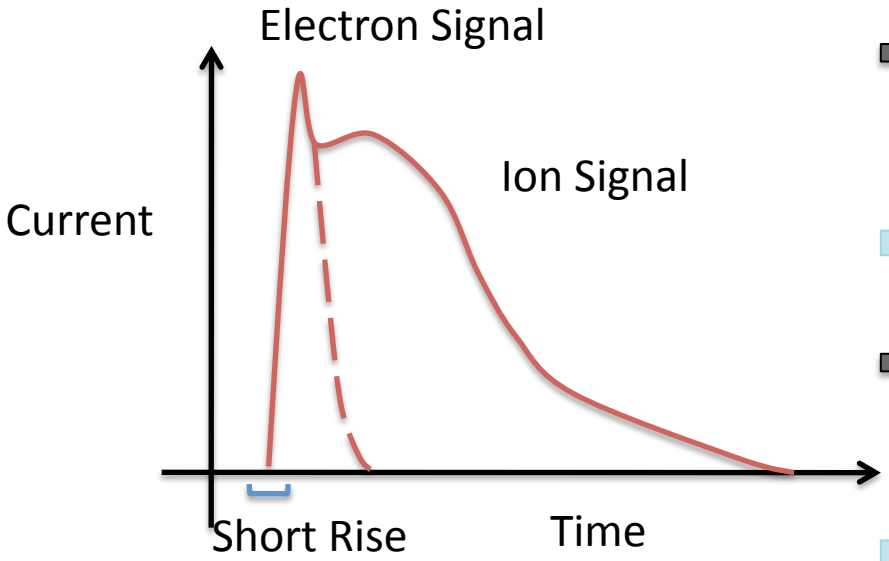
Readout:
250 MHz 8-bit AlazarTech PCI digitizer board

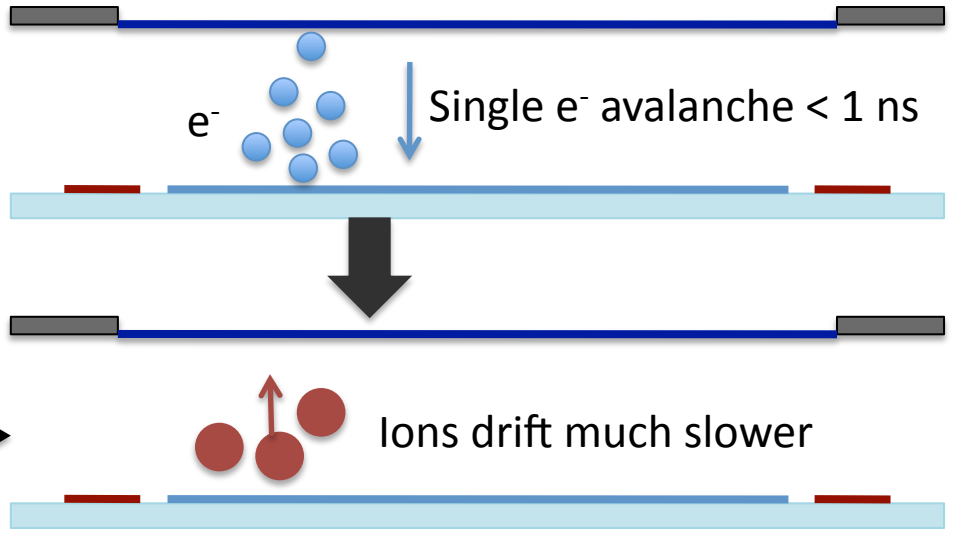
	Mesh	Anode	Veto
Preamp	Route2Electronics	Cremat	Cremat
	HS-AMP-CF	CR-113	CR-112
Gain	80	1.5 mV/pC	15 mV/pC
Rise Time	1 ns	20 ns	20 ns
Spark Protection?	Yes (built in)	Yes	Yes

Expected Signals

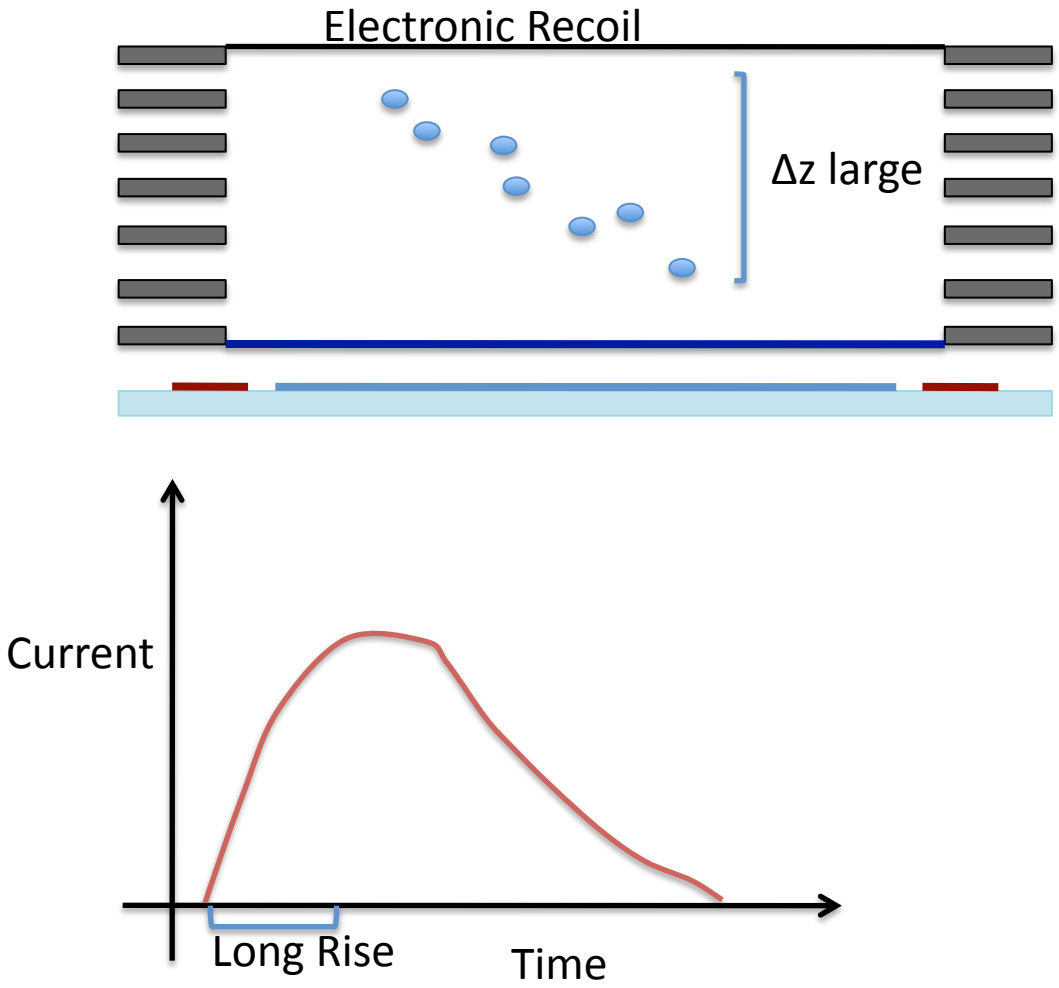


1. Compact track of ionization
2. Electrons reach amplification region at same time
3. See very fast rising edge to a peak from amplified electron signal
4. Ions drifting in amplification region create a broader plateau or second peak

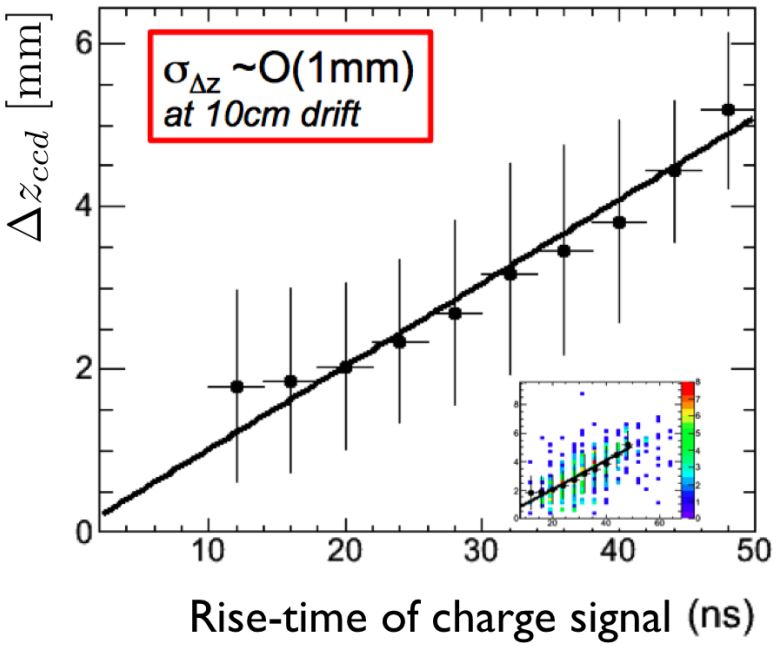


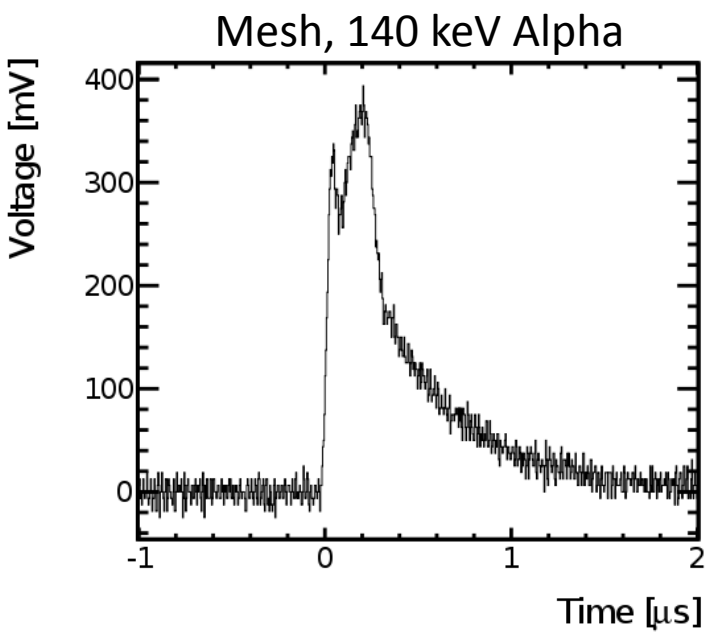


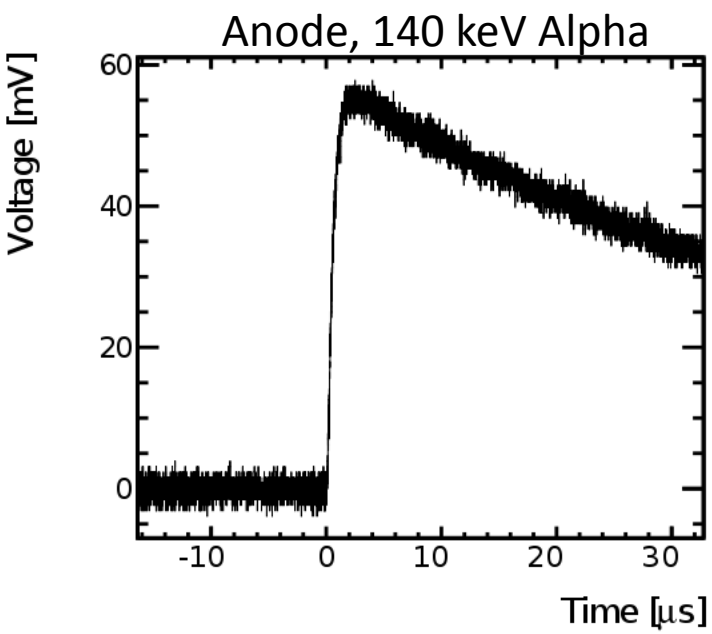
Expected Signals

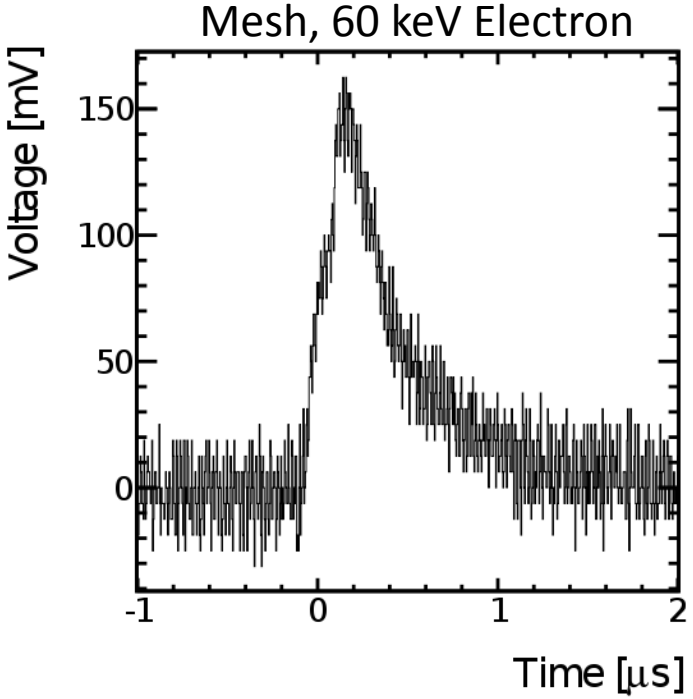


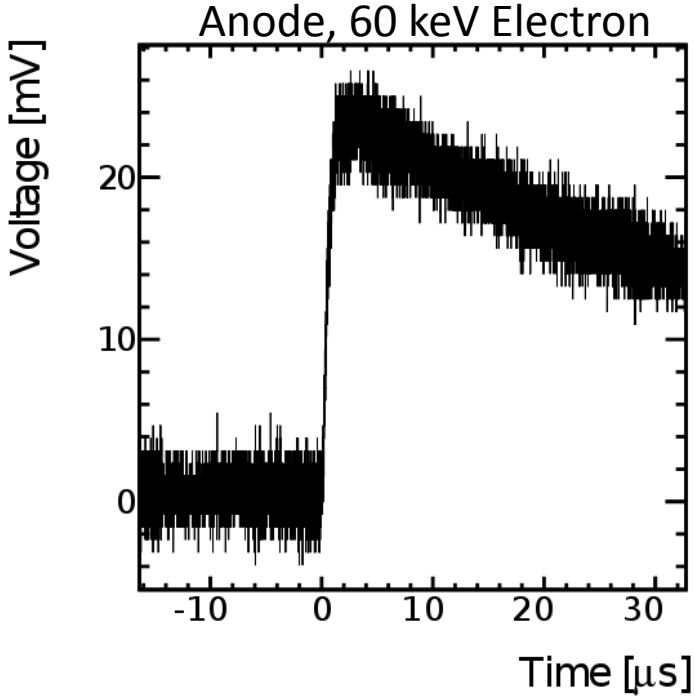
From low energy alpha tracks



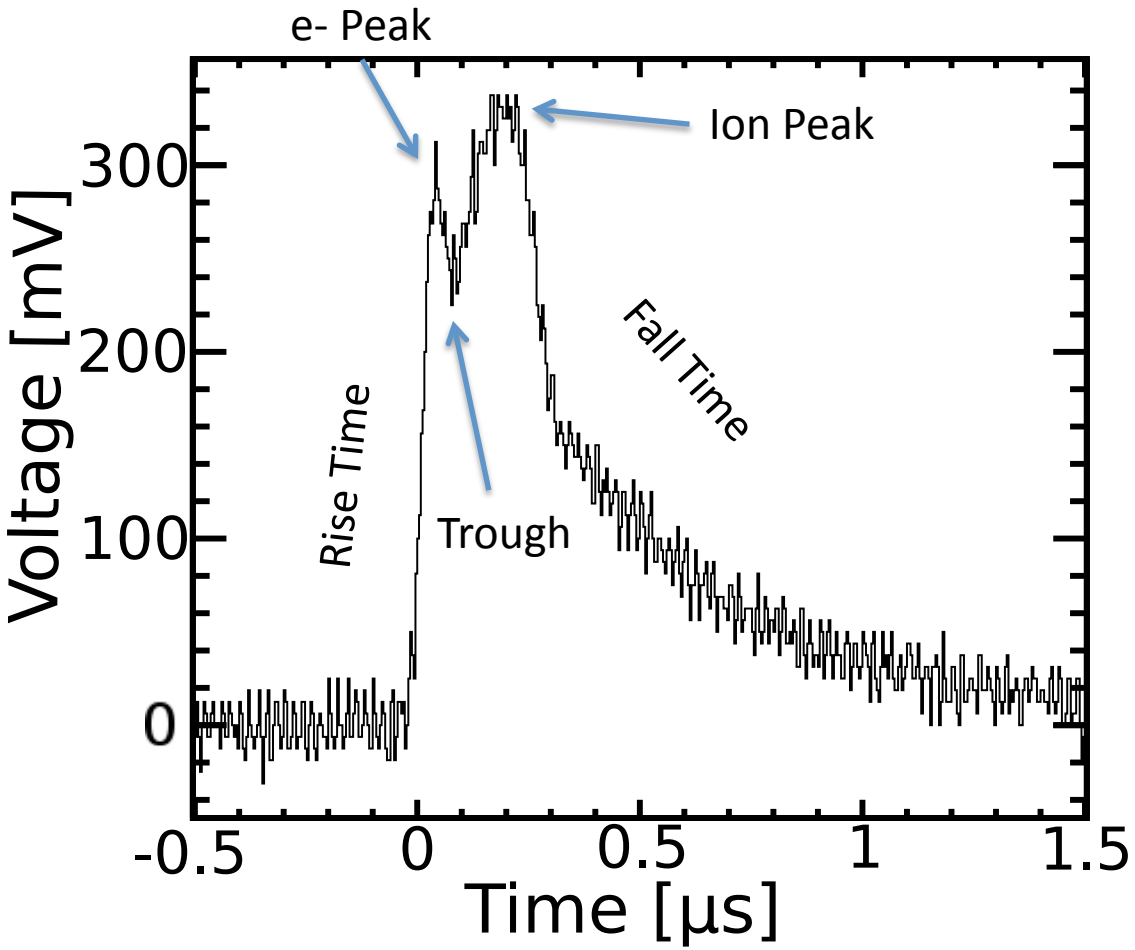

Mesh, 140 keV Alpha
Voltage [mV]
400
300
200
100
0
-1
0
1
2
Time [μs]


Anode, 140 keV Alpha
Voltage [mV]
60
40
20
0
-10
0
10
20
30
Time [μs]


Mesh, 60 keV Electron
Voltage [mV]
150
100
50
0
-1
0
1
2
Time [μs]


Anode, 60 keV Electron
Voltage [mV]
20
10
0
-10
0
10
20
30
Time [μs]

Mesh Trace Reconstruction



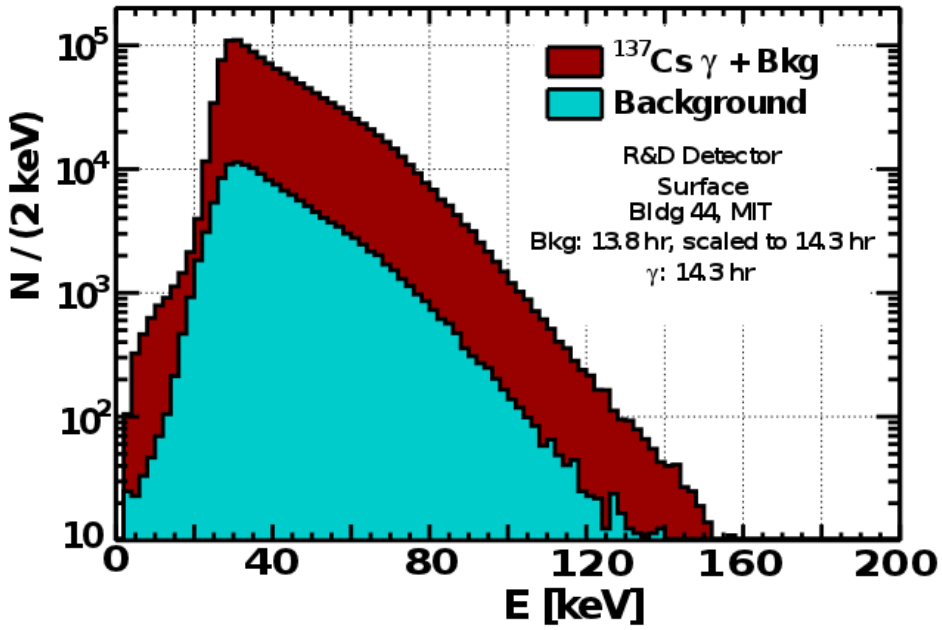
$$\int V\,dt \propto E$$

Electronic Recoils

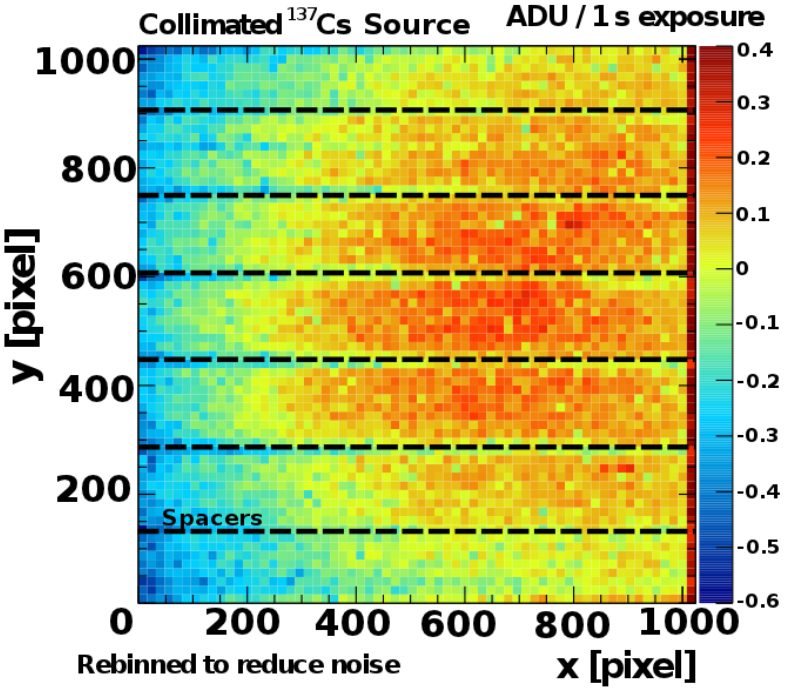
R&D Detector, Surface Lab at MIT
1 mm diffusion over 10 cm drift
Same mesh/anode design & electronics as for our larger detectors

- Can see in charge but not CCD
- Developed analysis to identify and reject e- charge signals
- Can use to measure our blindness to e- tracks
- ^{241}Am alpha to calibrate, set cuts (see only last few mm of tracks)
- ^{137}Cs source to generate electron recoils

Recoils from Cs-137 Gammas



25 γ per 1 s exposure



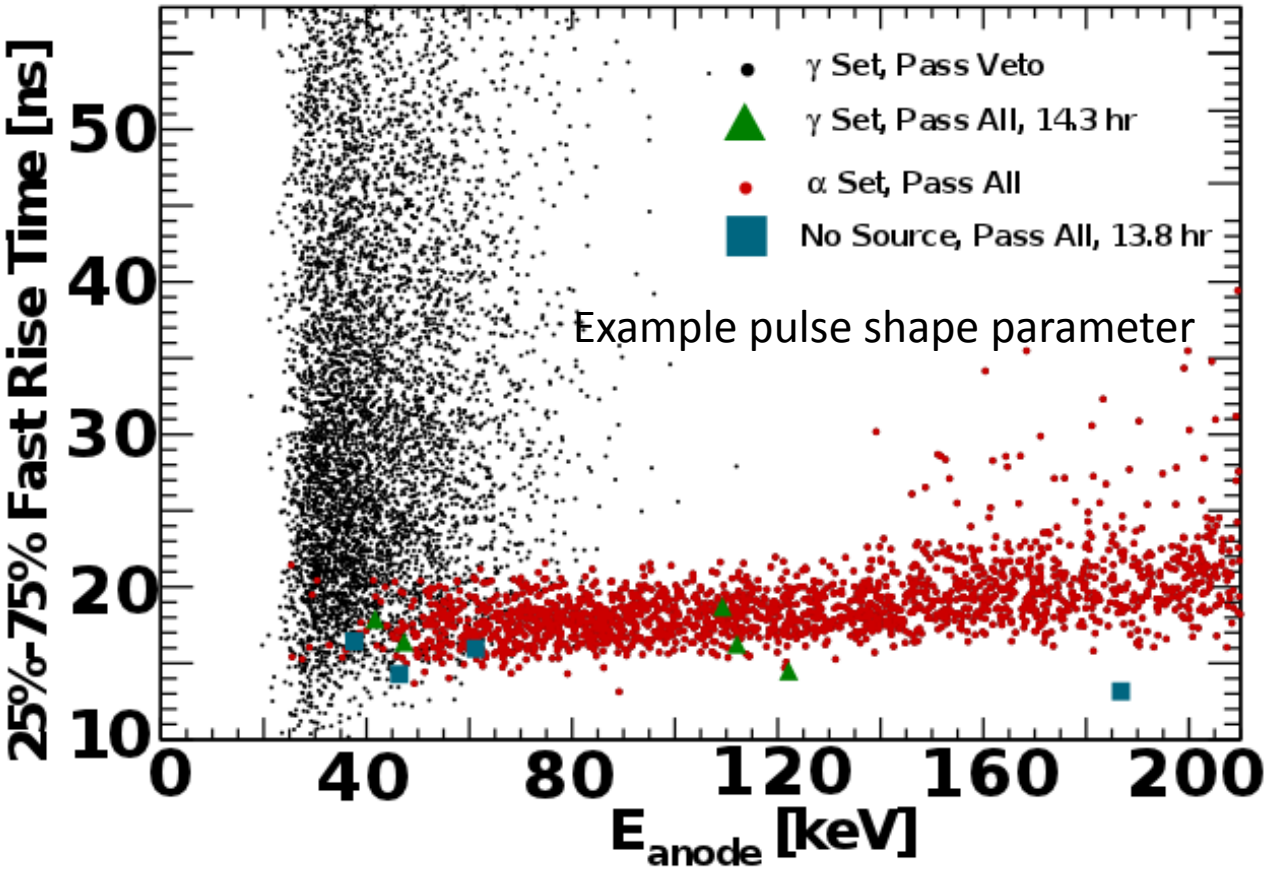
Trigger at about 30 keV, see lower energies from pileup (negligible in physics runs) & small baseline drift

~10^6 recoils with E>30 keV (charge signal)

~40 CCD tracks (incl. CCD artifacts) after loose cuts

2/3 occur in fiducial volume (imaged region)

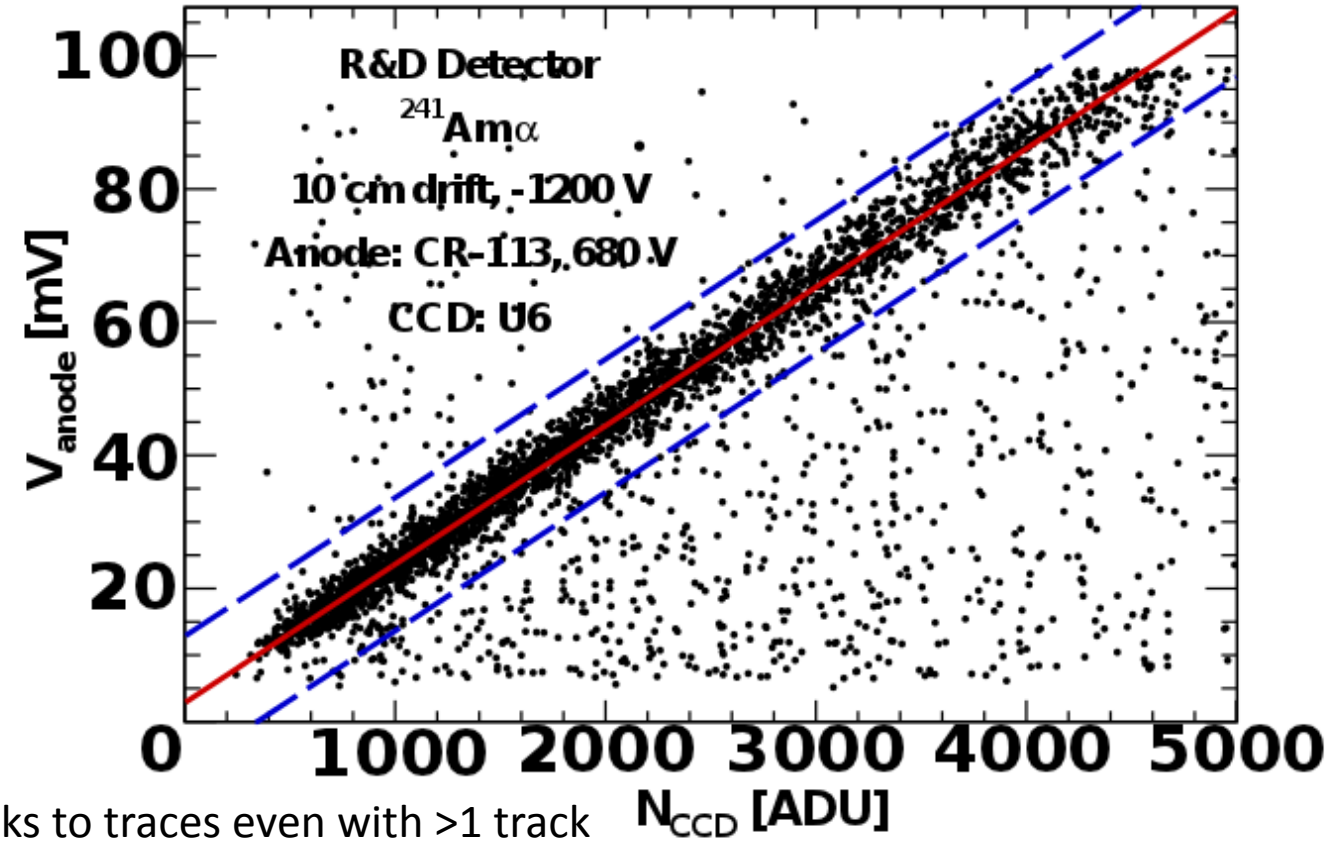
Pulse Shape Analysis



- Veto + mesh pulse shape rejection of e- charge traces better than 10^{-3}
- Charge cut efficiency > 90% for nuclear recoils seen in CCD (incl. CCD/Trace matching)

Comparison to CCD Tracks

Which CCD track belongs to which trace?
Red: Best fit
Blue: Good Match: 3.5σ (~35 keV)

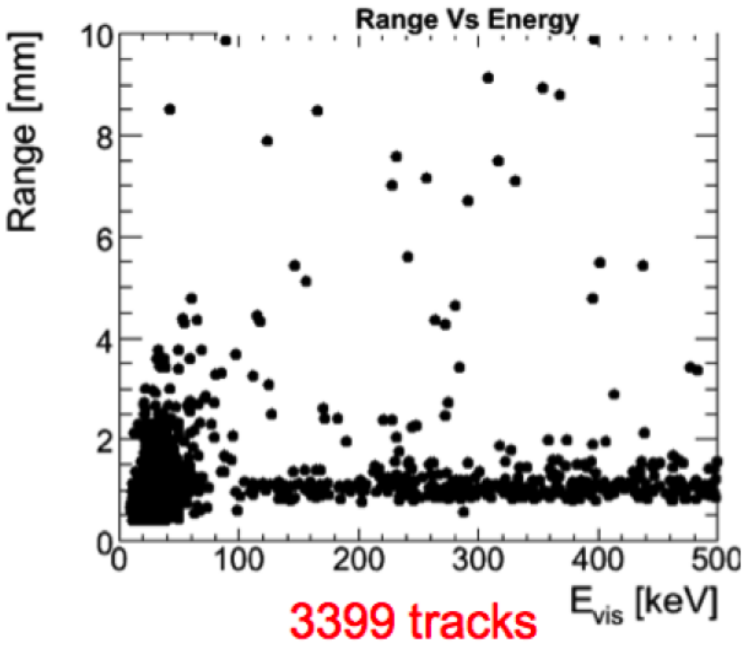


Match tracks to traces even with >1 track
Remove remaining gamma traces, CCD artifacts

Rejection of CCD Artifacts

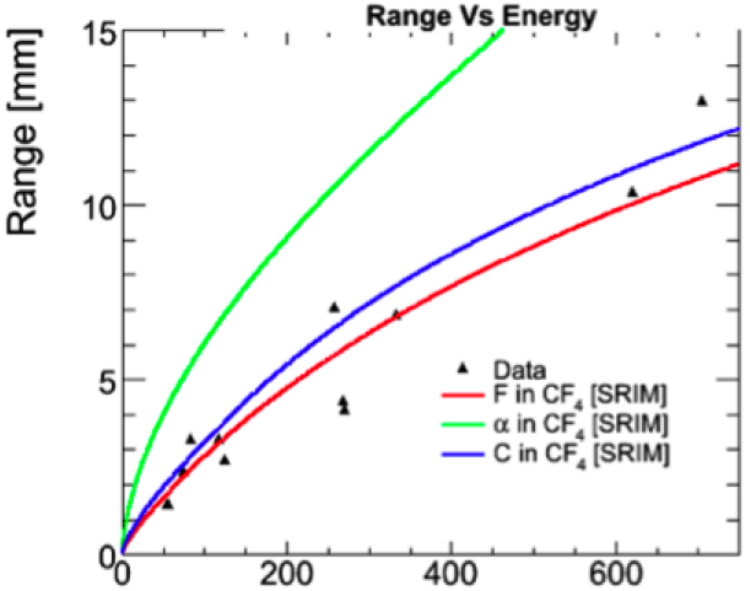
14 hr surface run, R&D detector
No sources

Recoil candidates in CCD only



3399 tracks

+ charge in central anode, not veto



12 tracks – all nuclear recoils

Most: Hot pixels (low range, high energy)
Residual bulk images (low energy, range)

Final Results (Preliminary)

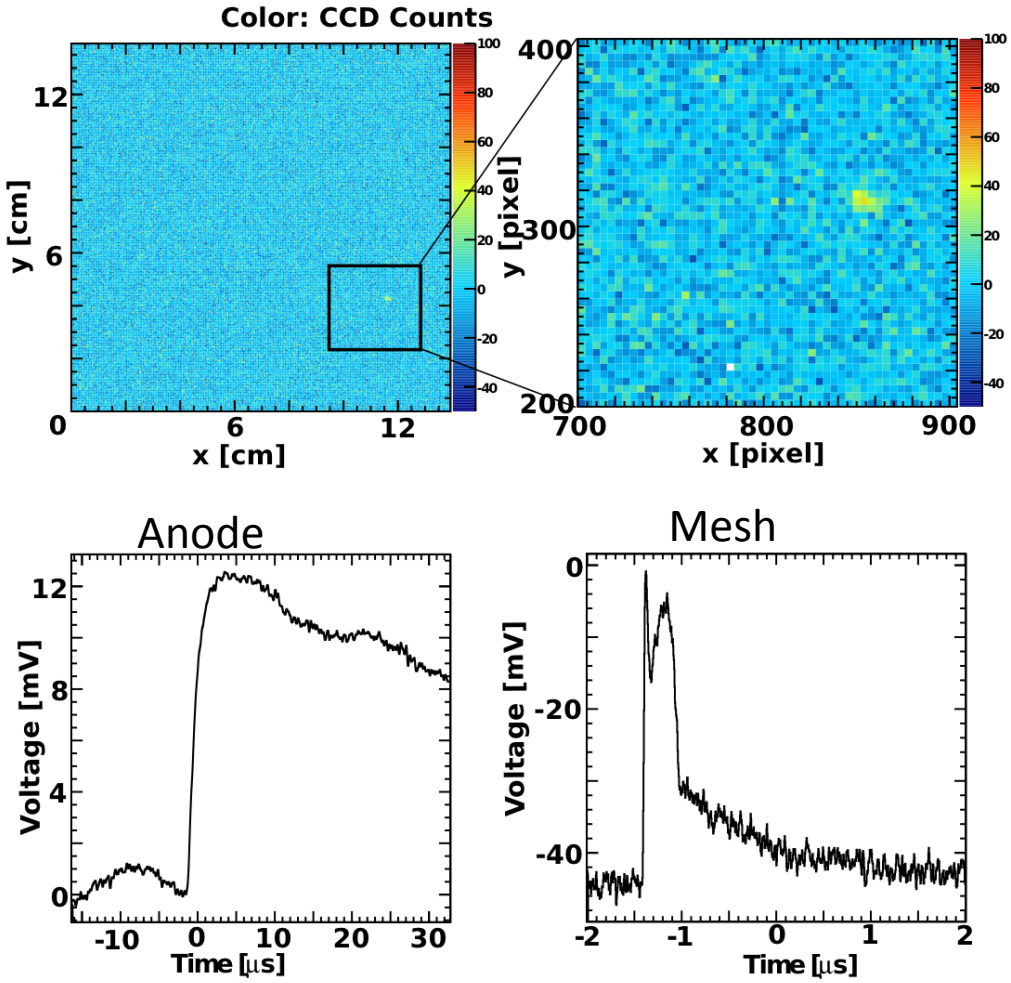
- In 40-200 keV range, see
  - 5 events, gamma dataset
  - 4 events, source free dataset
  - Look like typical nuclear recoils or alphas
  - i.e. see 0 of ~580k e- recoil charge signals (statistics limited)
  - 90% upper limit on e- misidentification of 1 in 170,000
  - True discrimination power likely much better
- Remaining CCD artifacts also eliminated

Future Outlook

- Deploy to other detectors
- Use neutrons to get F and C recoils (see right: event from AmBe n source, WIPP)

Summary:

1. Can remove e- charge signals and do not see CCD tracks: not a major expected background for DMTPC
2. Can remove CCD artifacts with charge/light matching
3. Addition of charge channels does not affect efficiency much

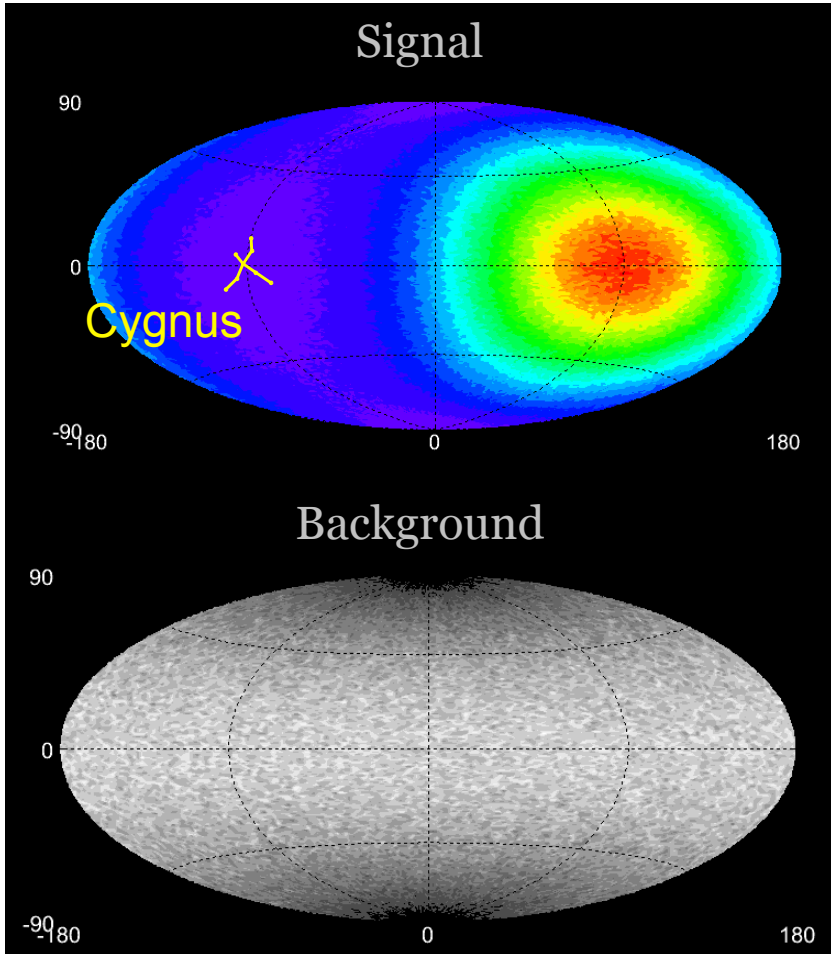


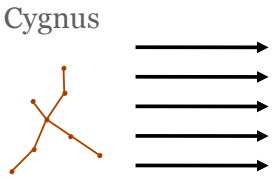
Thank You!

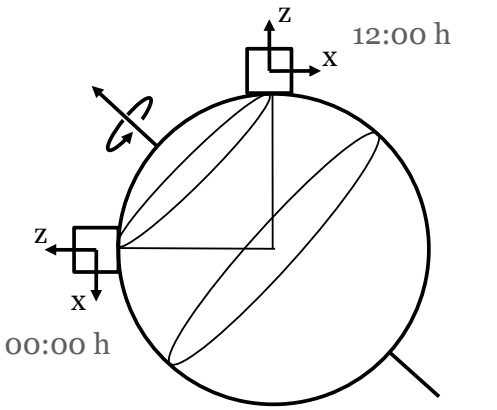
DMTPC Connex, WIPP, Aug. 2010

Backup Slides

The WIMP Wind

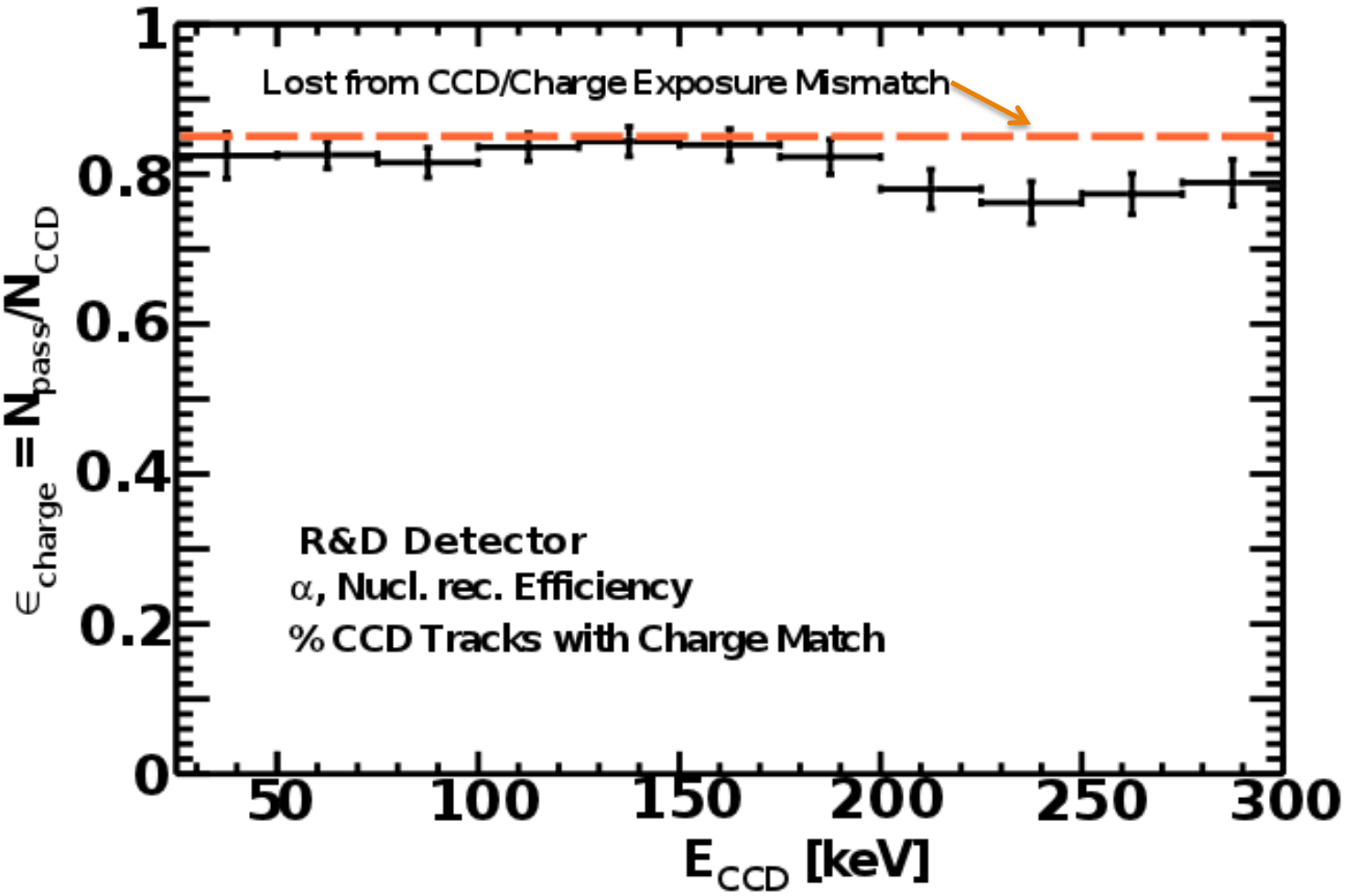






Spergel, PRD, 1988

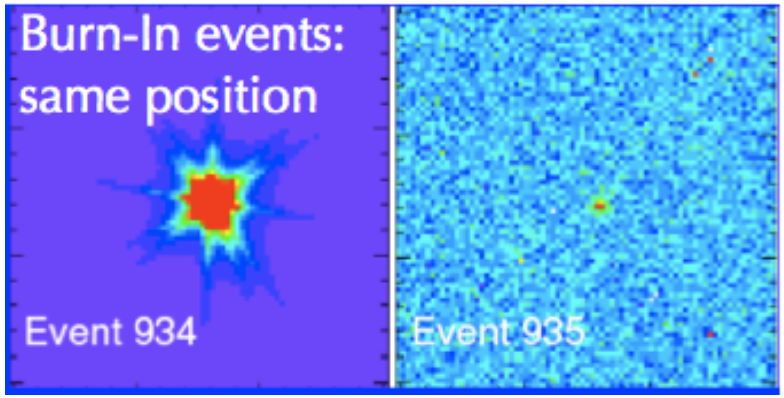
Charge Cut Efficiency



CCD Artifacts

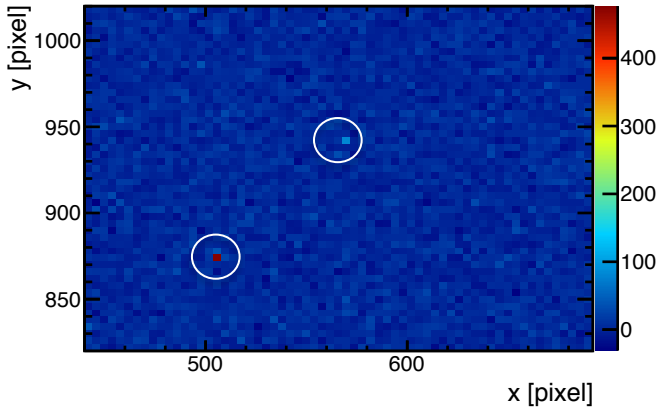
Residual Bulk Images

- Charge Trapped, gradually disappears from thermal motion



Hot Pixels

- Persistent pixels with high number of counts
- Value not stable enough to subtract



Also, muons and radioactive decays directly in CCD silicon chip